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TECHNICAL PROGRESS REPORT

COMPONENT NAME: PRESSURE SWITCH  
CONTRACT NUMBER: AF04(647)-158  
PERIOD COVERED: 1 FEBRUARY - 29 FEBRUARY 1960

TECHNICAL DISCUSSION -- MEDIUM PRESSURE SWITCH

THE MEDIUM PRESSURE SWITCH QUALIFICATION TESTS WERE COMPLETED DURING THIS REPORTING PERIOD, AND ALL UNITS SUCCESSFULLY PASSED THESE VERY STRINGENT SERIES OF TESTS. THE MEDIUM PRESSURE SWITCHES HAVE, AS A RESULT OF THE QUALIFICATION TESTS, SUCCESSFULLY MET ALL OF THE REQUIREMENTS LISTED IN THE DETAIL SPECIFICATION, R&D 158-15, AND HAVE SUCCESSFULLY PASSED THE QUALIFICATION TEST SPECIFICATION REQUIREMENTS OF R&D 158-16.

THERE WERE TWO QUESTIONS WHICH AROSE, HOWEVER. BOTH QUESTIONS PERTAINED TO THE 1000 PSI 45% DEADBAND PRESSURE SWITCH, SERIAL NUMBER 46. BECAUSE OF THE PRESS OF TIME, THE TEMPERATURE COMPENSATION ON THIS PRESSURE SWITCH COULD NOT BE SET TO WITHIN THE TOLERANCE LIMITS DEFINED IN THE SPECIFICATION, AND THE UNIT WAS SENT THROUGH THE QUALIFICATION TESTS ALTHOUGH IT EXHIBITED AN OUT-OF-TOLERANCE CONDITION. ALSO OCCURRING ON THIS PRESSURE SWITCH WAS A FIRST ACTUATION "STICKING" WHICH OCCURS AFTER EACH MAJOR CHANGE IN TEMPERATURE. THIS STICKING OCCURS TO A MINOR DEGREE ON ALL TEMPERATURE COMPENSATED PRESSURE SWITCHES, AND BECAUSE OF THE SEVERE COMPENSATION REQUIRED FOR THIS PARTICULAR SETTING, IS AGGRAVATED ON THIS UNIT. FREBANK COMPANY BELIEVES THAT THESE TWO ITEMS ARE MINOR AND CAN BE READILY SOLVED IN A PRODUCTION DELIVERY SITUATION ALTHOUGH THE COMBINATION OF CIRCUMSTANCES WHICH OCCURRED DURING THE QUALIFICATION PRESSURE SWITCH ASSEMBLY COMBINED TO PRESENT AN APPARENT PROBLEM.

THE FINAL REPORT IS NOW BEING COMPLETED, AND, WITH THE RECEIPT OF THE TEST DATA FROM THE QUALIFICATION TESTING, SHOULD BE READY FOR PUBLICATION DURING THE NEXT REPORTING PERIOD.

THE SPECIFICATIONS AND DRAWINGS FOR THE MEDIUM PRESSURE SWITCH WERE REVISED AND BROUGHT UP-TO-DATE IN ORDER TO REFLECT THE LATEST PERFORMANCE CHARACTERISTICS OF THE FINAL CONFIGURATIONS.

IN ANSWER TO A REQUEST FROM THE PROJECT MONITORS, STAINLESS STEEL COMPONENTS WERE MADE FOR THE MEDIUM PRESSURE SWITCH IN ORDER TO PROVIDE COMPATIBILITY WITH EXOTIC PROPELLANTS WHICH THIS UNIT MAY BE REQUIRED TO SENSE. THE KNOWLEDGE OF

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MANUFACTURE OF BERYLLIUM COPPER DIAPHRAGMS ALLOWED THE EASY MANUFACTURE OF EQUIVALENT DIAPHRAGMS OF 17-7 PH STAINLESS STEEL. THE USE OF THIS CORROSION RESISTANT DIAPHRAGM AND A CORROSION RESISTANT STEEL PORT MAKES THE DIAPHRAGM SUITABLE FOR OPERATION WITH RED FUMING NITRIC ACID, NITROGEN TETROXIDE AND OTHER CORROSIVE PROPELLANTS WITH NO CHANGE IN THE PERFORMANCE OF THE UNIT OTHER THAN A SLIGHT INCREASE IN COMPONENT WEIGHT.

#### MILEPOSTS -- MEDIUM PRESSURE SWITCH

THE TERMINATION OF QUALIFICATION TESTING ON THE MEDIUM PRESSURE SWITCH LEAVES ONLY THE PRESENTATION OF THE FINAL REPORT, THE DELIVERY OF THE AIR FORCE UNITS AND THE SPECIFICATIONS AND DRAWINGS TO BE ACCOMPLISHED AS REQUIREMENTS FROM THE STATEMENT OF WORK FROM THIS CONTRACT. IT IS ANTICIPATED THAT THESE WILL BE ACCOMPLISHED DURING THE NEXT REPORTING PERIOD.

#### TECHNICAL DISCUSSION -- LOW PRESSURE SWITCH

THE DEMONSTRATION TESTS ON THE LOW PRESSURE SWITCH OCCURRED DURING THIS REPORTING PERIOD. THE ASSEMBLY OF THE DEMONSTRATION TEST UNITS WAS DELAYED BECAUSE OF SEVERAL PROBLEMS WHICH AROSE. THE FIRST PROBLEM CONCERNED THE PLATING OF THE MAGNESIUM ACTUATION SHAFTS. THIS PROBLEM HAD APPARENTLY BEEN SOLVED PRIOR TO THE PREDEMONSTRATION TESTS BUT DURING THE ASSEMBLY OF THE DEMONSTRATION UNITS, THE NICKEL PLATING BLISTERED UNDER APPLICATION OF SOLDERING HEAT TO THE MAGNESIUM SHAFTS. THE MAGNESIUM SHAFTS WERE REPLACED, AND THE MORE CLOSELY CONTROLLED PLATING PROCESS ALLOWED THE SOLDERING WITHOUT THE UNDESIRABLE BLISTERING WHICH HAS PREVIOUSLY OCCURRED.

THE BERYLLIUM COPPER DIAPHRAGMS MADE FOR THE LOW PRESSURE SWITCH HAD EXHIBITED SOME SCALING DURING THE ANNEALING REQUIRED FOR FORMATION. PREVIOUS ATTEMPTS AT REMOVING THIS SCALING BY ETCHING, VAPOR HONING, ETC., HAD BEEN UNSUCCESSFUL. A TUMBLING PROCESS TO REMOVE HEAT TREAT SCALE WAS DEVELOPED. THIS PROCESS CONTAINED NO ACIDS AND ALLOWED THE COMPLETE CLEANING OF THE DIAPHRAGMS WITHOUT DEFORMATION OR DELETERIOUS EFFECTS TO THE DIAPHRAGM CONFIGURATION. THE PLATING PROCESS DEVELOPED FOR THE LOW PRESSURE SWITCH DIAPHRAGMS IS AS FOLLOWS:

(1) ACID CLEANING -- 30% NITRIC ACID SOLUTION, (2) FLASH NICKEL PLATING, (3) .00006 INCH COPPER PLATING, (4) .00006 INCH SILVER PLATING, (5) .00006 INCH GOLD PLATING.

THE OTHER COMPONENT WHICH CAUSED ASSEMBLY DELAYS WAS THE BELLEVILLE SPRING WASHERS. THE EXACT CONFIGURATION REQUIRED OF THE SPRING MEMBERS HAS RESULTED IN HIGH SCRAP RATIOS, AND EXPERIENCE HAS SHOWN THAT ONLY THE BELLEVILLE SPRINGS WHICH CORRESPOND EXACTLY TO THE DETAIL PRINTS WERE SATISFACTORY.

THE UNITS ENTERED THE DEMONSTRATION TEST PHASE OF THE PROGRAM EARLY IN THIS REPORTING PERIOD, AND WITH MINOR EXCEPTIONS WERE SUCCESSFULLY COMPLETED. THE FEW PROBLEMS THAT OCCURRED ARE DESCRIBED BELOW:

**PROOF PRESSURE:** DURING PROOF PRESSURE, TWO UNITS EXPERIENCED INTERNAL AND EXTERNAL LEAKAGE. THESE UNITS WERE LATER FOUND TO BE INCORRECTLY SOLDERED AS THE DIAPHRAGMS HAD NOT BEEN SUFFICIENTLY TINNED. THIS PROBLEM WAS SOLVED BY AN INCREASE IN THE TORQUE USED TO CLAMP THE DIAPHRAGM BETWEEN THE BODY AND INLET PORT AND BY A CAREFUL TINNING OF THE DIAPHRAGM PERIPHERY.

**TEMPERATURE COMPENSATION:** A TEMPERATURE COMPENSATION OBTAINED WITH THE DEMONSTRATION UNITS WAS MARGINAL IN THAT THE PRESSURE SWITCH IS SENSITIVE TO THE TEMPERATURE GRADIENT THAT OCCURS WITH THE PRESSURIZATION OF THE INLET PORT WITH LIQUID OXYGEN AT  $-300^{\circ}\text{F}$  WHILE THE PRESSURE SWITCH BODY IS EXPOSED TO AN AMBIENT TEMPERATURE OF  $70^{\circ}\text{F}$  (ROOM AMBIENT TEMPERATURE) OR  $200^{\circ}\text{F}$ . THE BELLEVILLE SPRINGS USED FOR THE DEMONSTRATION PRESSURE SWITCHES WERE MARGINAL IN THICKNESS, H/T RATIO AND HEAT TREAT, AND, AS A RESULT, COULD NOT BE TEMPERATURE COMPENSATED EXACTLY AS IS THEORETICALLY POSSIBLE. THE BELLEVILLE SPRINGS ORDERED FOR THE QUALIFICATION AND AIR FORCE DELIVERY LOW PRESSURE SWITCHES WILL BE MADE TO THE EXACT REQUIREMENTS OF THE DRAWING.

**ICING TESTS:** THERE WERE NO PROBLEMS FOUND IN THE ICING SERIES OF TESTS.

**HUMIDITY:** NO PROBLEMS OCCURRED.

**DIELECTRIC:** NO PROBLEMS.

**ACCELERATION:** A DECREASE IN INCREASING PRESSURE SETTING WAS NOTED DURING ACCELERATION TESTS. THESE CHANGES IN SETTING WERE BEYOND THOSE ALLOWED BY THE SPECIFICATION; HOWEVER, THE

INSTRUMENTATION ON THE ACCELERATION TEST FIXTURE IS SUSPECT, AND IT IS BELIEVED THAT THE GASIFICATION WHICH OCCURRED, ESPECIALLY IN THE LOW PRESSURE RANGE, WAS SUFFICIENT TO DISRUPT THE PRESSURE MONITORING.

**VIBRATION:** SWITCH CHATTER WAS FOUND IN THE LOW DEADBAND PRESSURE SWITCHES AT 25G'S. THIS CHATTER IS ATTRIBUTABLE TO THREE POSSIBLE REASONS: (1) THE SWITCH ELEMENT WAS OVERHEATED DURING THE SOLDERING ASSEMBLY OF THE PRESSURE SWITCH -- A PROBLEM WHICH PLAGUED THE MEDIUM PRESSURE SWITCH PROGRAM. (2) THE PRESSURIZATION HOSE ATTACHED TO THE PRESSURE SWITCH UNDER TEST WAS INCREASING THE G FORCES SENSED BY THE UNIT. (3) THE SWITCH ELEMENTS USED WERE UNSATISFACTORY AND HAD "DEADBREAKS". THE CHATTER WHICH OCCURRED WAS IN THE RANGE OF 1800 TO 2000 CYCLES PER SECOND AND OCCURRED WHILE THE PRESSURE SWITCHES WERE PRESSURIZED TO 98% OF ACTUATION PRESSURE. THIS VIBRATION SENSITIVITY IS UNDER INTENSIVE INVESTIGATION.

**ALTITUDE:** THERE WAS A SETTING SHIFT WITH ALTITUDE FOR ALL PRESSURE SWITCHES -- THE SHIFT BEING A MAXIMUM OF 5%. THIS SETTING SHIFT PREVIOUSLY MENTIONED IS CAUSED BY THE EFFECTIVE AREA CHANGE OF THE AMBIENT PRESSURE SENSING DIAPHRAGM. THE REVISED PRESSURE SWITCH TOLERANCES WILL ALLOW THIS SHIFT TO OCCUR.

**ENDURANCE TEST:** TWO UNITS FAILED ENDURANCE. THE 100 PSI, 45% DEADBAND PRESSURE SWITCH, SERIAL NUMBER 2, FAILED AT 1000 CYCLES BECAUSE OF EXCESSIVE LEAKAGE PASTED THE DIAPHRAGM. THE 100 PSI, 5% DEADBAND UNIT FAILED WHEN THE SWITCH ELEMENT NORMALLY OPEN CIRCUIT REMAINED IN THE NORMALLY CLOSED POSITION. THIS FAILURE IS BEING INVESTIGATED.

THE REMAINING PRESSURE SWITCHES COMPLETED 20,000 CYCLES OF OPERATION.

**LIMITS OF OPERATION:** UNDER LIMITS OF OPERATION, THE LOW PRESSURE SWITCH WAS VIBRATION TESTED TO A MAXIMUM OF 45G'S. THE UNIT, SERIAL NUMBER 6, WAS TESTED AT INCREASING VIBRATION ACCELERATION LEVELS TO 40G'S WITH NO SWITCH CHATTER BEING EVIDENT. THIS TESTING, HOWEVER, SHOWED THAT THE ACTUATION PRESSURE DECREASES WITH INCREASING G LEVEL, AND AT 40G'S, THE ACTUATION PRESSURE DECREASES BY 16%. AT AN ACCELERATION LEVEL OF 45G'S, THE UNIT EXHIBITED SWITCH CHATTER DEFINING THE MAXIMUM VIBRATION ACCELERATION RESISTANCE OF THE HIGH DEADBAND, LOWEST PRESSURE SWITCH.

THE BURST PRESSURE OF THE LIMITS OF OPERATION PRESSURE SWITCH TESTED WAS LESS THAN THAT REQUIRED BY THE SPECIFICATION. THE DIAPHRAGM PULLED LOOSE AT A PRESSURE OF 780 PSI. THE BURST PRESSURE REQUIREMENTS ARE 1000 PSI MINIMUM. SUBSEQUENT INVESTIGATION SHOWED THAT ALL OF THE DEMONSTRATION UNITS WERE NOT SUITABLY TORQUED SO THAT THE INLET PORT WAS NOT CLAMPING THE DIAPHRAGM TO THE BODY. THIS REASON ALSO ALLOWED THE LEAKAGE WHICH OCCURRED UNDER PROOF PRESSURE.

ENDURANCE TESTING ON SERIAL NUMBER 2 SHOWED THAT THE LIMITS OF OPERATION ON THIS UNIT WERE 21,700 CYCLES — A MARGIN OF ONLY 1700 CYCLES OVER THE REQUIRED ENDURANCE LIFE. FAILURE WAS CHARACTERIZED BY LEAKAGE AROUND THE DIAPHRAGM, AND THIS, AGAIN, IS ATTRIBUTABLE TO AN INSUFFICIENT TIGHTENING OF THE INLET PORT OF THE PRESSURE SWITCH BODY. THE ELECTRICAL SWITCH ELEMENT ALSO EXHIBITED AN OPEN CIRCUIT, PROBABLY DUE TO LEAKAGE PASSED THE DIAPHRAGM INTO THE MECHANISM HOUSING.

THE TEMPERATURE LIMITS OF SERIAL NUMBER 5 SEEMED SATISFACTORY IN THAT THE PRESSURE SWITCH WAS OPERATED AT  $+300^{\circ}\text{F}$  WITH NO DELETERIOUS EFFECTS. THIS SEEMS TO BE THE TEMPERATURE LIMIT BECAUSE OF THE PLASTIC SWITCH ELEMENT CASE USED FOR THIS PRESSURE SWITCH.

LIMITS OF OPERATION ACCELERATION TESTS SHOW THAT THIS UNIT IS EXTREMELY RESISTANT TO LINEAR ACCELERATION. THE UNIT WAS TESTED TO AN ACCELERATION LEVEL OF 60G'S WITHOUT DELETERIOUS EFFECTS. THERE WAS, HOWEVER, A SLIGHT REDUCTION IN ACTUATION PRESSURE WHICH OCCURRED. THIS REDUCTION WAS NOT CONSIDERED SERIOUS.

#### MILEPOSTS — LOW PRESSURE SWITCH

THE ASSEMBLY AND QUALIFICATION TESTING OF THE LOW PRESSURE SWITCH CANNOT BE ACCOMPLISHED WITHIN THE PRESENT SCHEDULES. FREBANK COMPANY HAS REQUESTED THAT AN EXTENSION OF TIME AND ADDITIONAL FUNDS BE GRANTED TO ALLOW THE COMPLETION OF THIS PROGRAM. IT IS ANTICIPATED THAT THIS PROGRAM CAN BE COMPLETED WITHIN AN ADDITIONAL EIGHT WEEKS.

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